WYOMING GAME AND FISH

FISH DIVISION

ADMINISTRATIVE REPORT

TITLE Instream Flow Studies on Coal Creek, a Bonneville Cutthroat Trout (*Oncorhynchus clarki utah*) Stream.

PROJECT: IF-4093-07-9302

AUTHOR: Paul D Dey and Thomas C Annear

DATE: August 1994

ABSTRACT

Instream flow studies were initiated in 1993 on Coal Creek to complement ongoing monitoring of Bonneville cutthroat trout (BRC) index streams described in a recent management plan (Remmick et al. 1993). Studies were designed to determine instream flows needed to maintain or improve BRC populations.

Physical Habitat Simulation (PHABSIM), the Habitat Quality Index (HQI) and the Habitat Retention Method were used to derive flow recommendations. Recommendations for the reach between Sawmill Creek and the confluence with Smiths Fork River are as follows: April 15 - June 30 = 7.5 cfs, July 1 - September 30 = 3.0 cfs, and October 1 - April 14 = 1.8 cfs.

INTRODUCTION

Bonneville Cutthroat trout (*Oncorhynchus clarki utah*) populations in Wyoming are restricted to tributaries of the Bear River - primarily the Thomas Fork and Smiths Fork watersheds. Physical, chemical, and biological characteristics of the Bear River drainage were inventoried between 1966 and 1977 (Miller 1977). Binns (1981) reviewed the distribution, genetic purity, and habitat conditions associated with populations of Bonneville cutthroat trout. Results of more recent population and habitat surveys are presented in Remmick (1981, 1987) and Remmick et al. 1993. In general, populations are limited by low flows, lack of riparian cover elements, thermal pollution arising in conjunction with low flows and reduced riparian vegetation, and silt pollution.

The Bonneville Cutthroat trout was recently petitioned for listing under the Endangered Species Act. Status review was initiated in response to concerns expressed by Idaho Fish and Game, the Desert Fishes Council and the Utah Wilderness Association. A 5-year management plan for Wyoming, which was developed by the Wyoming Game and Fish Department (WGFD) in coordination with the U.S. Forest Service (USFS) and U.S. Bureau of Land Management (BLM), outlines management goals and recommends criteria for listing Bonneville cutthroat trout as threatened (Remmick et al. 1993). The plan recommends that status decisions be made after a five-year population and habitat monitoring period. Fish management and other land management practices could be significantly affected by potential listing of Bonneville cutthroat trout as Threatened and Endangered. Identification and acquisition of Instream Flow water rights is a critical element to avoid such an action on all streams containing Bonneville cutthroat trout.

One objective outlined in the management plan is to "describe existing habitat conditions, establish habitat condition objectives, and determine the impacts of past, present or proposed land management activities for all index streams by 1997." Index streams include a range of stream types for which significant habitat information and data on Bonneville cutthroat trout populations exists. In pursuit of this objective, the Instream Flow Crew initiated studies in 1993 on the following index streams: Coal Creek (Howland), Huff Creek, and Hobble Creek. This report details the results of studies on Coal Creek.

Specifically, the objectives of this study were to 1) investigate the relationship between discharge and physical habitat for Bonneville cutthroat trout and, 2) determine an instream flow necessary to maintain or improve Bonneville cutthroat trout populations.

METHODS

Study Area

Coal Creek (Howland Creek) is a small tributary to Smiths Fork River (Fig. 1). Grazing and road impacts are extensive with exposed banks common. Grasses (*Poa* sp.) are the relatively dominant vegetation type while willows (*Salix* sp.) and sedges (*Carex* sp.) are patchily distributed, becoming more common higher in the watershed. Beaver activity is present about two miles upstream from the confluence with Smiths Fork River. Sagebrush (*Artemesia tridentata*) is the primary vegetation at lower elevations while scattered aspen (*Populus tremuloides*), and a few conifers including subalpine fir (*Abes lasiocarpa*), lodgepole pine (*Pinus contorta latifolia*), and Engelman spruce (*Picea engelmanni*) are present at the headwaters.

Bonneville cutthroat trout populations in Coal Creek were assigned an "A" purity rating by Dr. Robert Behnke (Remmick et al. 1993). This indicates a pure stock with no evidence of hybridization. Population data collected in 1992 from 1 station indicate an average of 264 trout/mile (Remmick et al. 1993). Average length was 7.0 in. (range = 5.4-11.2 in.).

A site with two separate segments was chosen to model all important habitat characteristics. Data were collected between May 11 and September 21, 1993. Collection dates and corresponding discharges are listed in Table 1. The upstream boundary of the site is immediately below the Sawmill Creek confluence (Township 26N, Range 118W, Section 16, SE 1/4). The lower study site (S1) contains 4 transects modeling two riffles, a run with fry habitat, and a pool (Appendix 1). The upper study site starts approximately 200 ft upstream and includes deep pool, bankside run, shallow pool, and riffle habitats. This reach was modeled at high flow with six transects. An additional hydraulic control transect was added at low flow. The chosen study sites, though degraded, include some of the best habitat available in this section of Coal Creek.

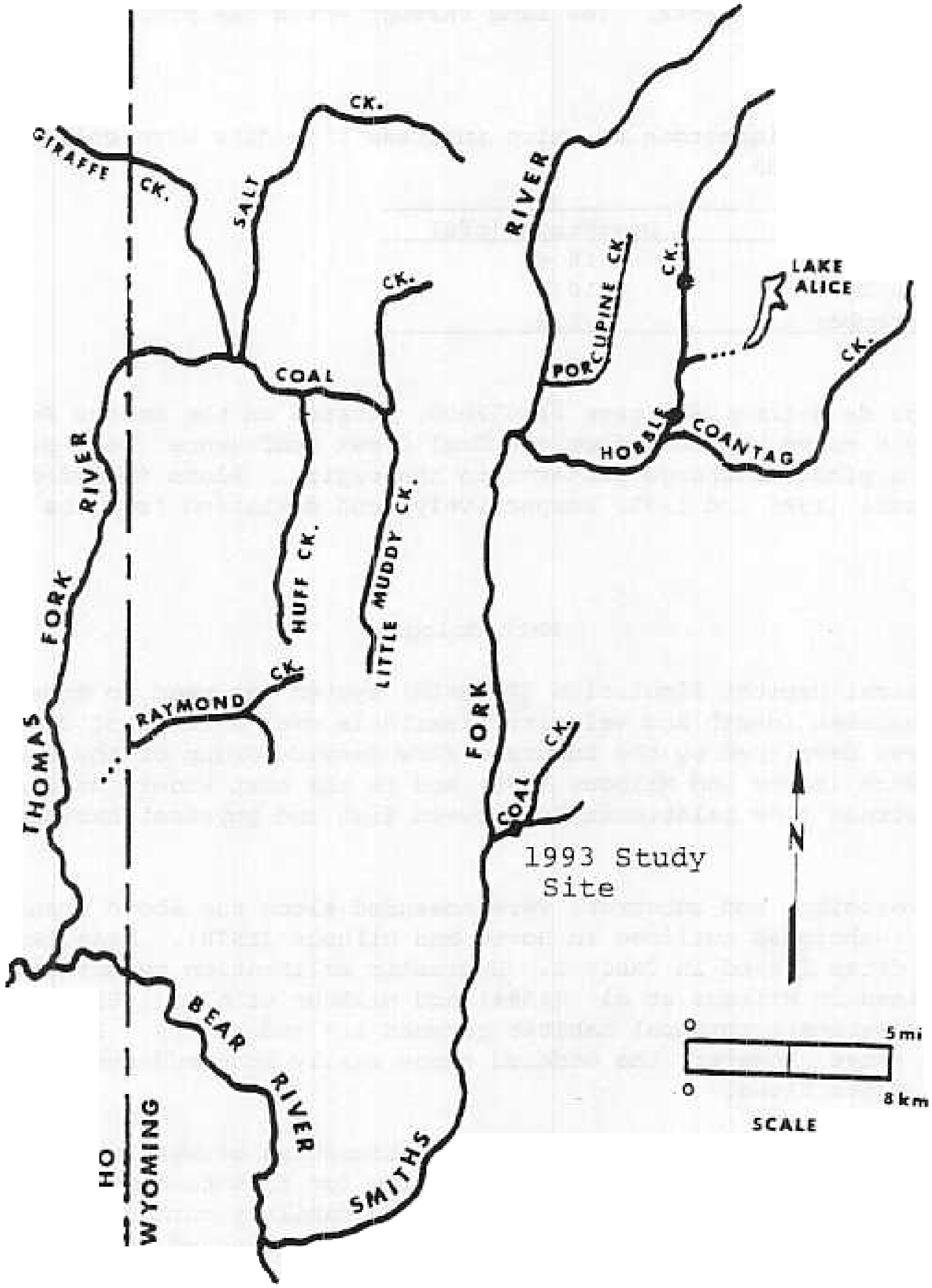

Figure T' Smiths Fork and Thomas Fork drainages

Instream flow filing recommendations derived from these sites were applied to an approximately 1 mile-long reach extending downstream from the Sawmill Creek confluence to the Smiths Fork. The land through which the proposed segment passes is entirely State owned.

Table 1 Dates and discharges at which instream flow data were collected from Coal Creek in 1993.

Date	Discharge (cfs)
May 11	16.4
June 22	10.8
September 21	2.9

Discharge data from USGS gage #10032000, located on the Smiths Fork River approximately 5 miles upstream from the Coal Creek confluence, were plotted to gain insight into typical discharge patterns in the region. Plots included high and low flow water years (1986 and 1992, respectively) and deviation from the 20 year mean discharge.

Methodologies

The Physical Habitat Simulation (PHABSIM) system was used to model the quantity of physical habitat (depth and velocity) available over a range of discharges. This methodology was developed by the Instream Flow Service Group of the U.S. Fish and Wildlife Service (Bovee and Milhous 1978) and is the most widely used method for assessing instream flow relationships between fish and physical habitat (Reiser et al. 1989).

Depth, velocity, and substrate were measured along the above transects according to techniques outlined in Bovee and Milhous (1978). Measurements were taken on the dates listed in Table 1. Hydraulic calibration techniques and modeling options outlined in Milhous et al. (1984) and Milhous et al. (1989) were employed to incrementally estimate physical habitat between 1.5 and 40 cfs. Precision declines outside this range; however, the modeled range easily accommodates the range of typical Coal Creek flows.

The PHABSIM model utilizes empirical relationships between physical variables (depth, velocity, and substrate) and suitability for fish to derive an estimate of weighted usable area (WUA) at various flows. Suitability curves for spawning Bonneville cutthroat trout were developed from data collected in 1994 from Huff Creek (Appendix 2). General cutthroat trout curves (Appendix 2, Bovee 1978) were used to determine discharge-physical habitat relationships for the fry, juvenile and adult life stages.

Critical Bonneville cutthroat trout life stages in Coal Creek and time periods of importance are identified in Table 2. Critical life stages are those life stages most sensitive to environmental fluctuations. Population integrity is sustained by providing adequate flow for critical life stages. In many cases, Rocky Mountain stream populations are constrained by spawning and young (fry and juvenile) life stage habitat bottlenecks (Nehring and Anderson 1993). On Coal Creek, observations indicate that spawning habitat is likely a critical factor influencing trout populations.

According to estimates by Binns (1981), spawning in Coal Creek (elevation 6590) should peak between about May 10 and June 1. To provide latitude for inter-annual flow and temperature variation, the spawning period should be recognized as April 15 to June 30. Even if spawning is completed by June 1, maintaining flows at a selected level throughout June will benefit incubation. The PHABSIM system was used to derive flow recommendations for spawning Bonneville cutthroat trout from April 15 to June 30 (Table 2). Physical habitat for adults, fry and juveniles was also determined with the PHABSIM system but was not used in deriving instream flow recommendations. These data were included for reference.

Table 2 Bonneville cutthroat trout life stages considered in development of instream flow recommendations for Coal Creek. Numbers indicate method used to determine flow requirements.

LIFE STAGE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Adult							1	1	1			
Spawning				2	2	2						
All stages	3	3	3							3	3	3

1 - Habitat Quality Index
2 - PHABSIM
3 - Habitat Retention

The Habitat Quality Index (HQI; Binns and Eisermann 1979, Binns 1982) was used to estimate trout production over a range of late summer flow conditions. This model was developed by WGF and received extensive testing and refinement. It has been reliably used in Wyoming for assessment of habitat gains or losses associated with projects that modify instream flow regimes. The HQI model includes nine attributes addressing biological, chemical, physical and hydrological aspects of available trout habitat. Results are expressed in Habitat Units (HUs), where one HU is defined as the amount of habitat quality that will support 1 pound of trout. HQI results were used to identify the average flow needed to maintain or improve existing levels of Bonneville cutthroat trout production between July 1 and September 30 (Table 2).

In the HQI analysis habitat attributes measured at various flow events are assumed to be typical of late-summer flow conditions. Under this assumption, HU estimates can be extrapolated through a range of potential late summer flows (Conder and Annear 1987). Coal Creek habitat attributes were measured on the same dates that PHABSIM data were collected (Table 1). Some attributes were mathematically derived to establish the relationship between discharge and trout production at discharges other than those measured. The estimate of average daily flow is from Binns (1981) and is based on watershed areas and flow at Smiths Fork gage #10032000.

The Habitat Retention method (Nehring 1979, Annear and Conder 1984) was used to identify maintenance flows at three riffle transects. Maintenance flow is defined as the continuous flow required to maintain minimum hydraulic criteria in riffle areas of a stream. Year-round maintenance of these criteria ensures passage between habitat types for all trout life stages. In addition, the criteria ensure adequate survival of benthic invertebrates. A maintenance flow is defined as the discharge for which any two of the three criteria in Table 3 are met for all appropriate transects. Instream flow recommendations from the Habitat Retention method are applicable year round except when higher instream flows are required to meet other fishery management purposes (Table 2).

Table 3 Hydraulic criteria for determining maintenance flow with the Habitat Retention method.

Category	Criteria
Mean Depth (ft)	Top width[1] X 0.01
Mean Velocity (ft/s)	1.00
Wetted Perimeter (%)[2]	50

1 - At average daily flow. Minimum = 0.2
2 - Percent of bank full wetted perimeter

RESULTS AND DISCUSSION

Discharge

Southwest Wyoming streams typically exhibit both annually and seasonally variable flows. On the annual scale, extended drought conditions, such as those in 1987-1992, are not uncommon. Seasonally, snowpack-derived flows are often quite high through June and drop to low levels in late fall and winter. For example, average June Smiths Fork River discharge was 1,400 cfs in 1986 (Fig. 2). Flows averaged less than 100 cfs throughout the winter. Furthermore, annual 1986 discharge was the highest in the last 20 years while 1992 discharge was low and followed 5 years of drought (Fig. 3).

PHABSIM Analysis

Weighted usable area estimates for four life stages of cutthroat trout are illustrated in Figure 4. PHABSIM analysis indicates that a flow of 7.5 cfs maximizes physical habitat for spawning (Fig. 4). Therefore, an instream flow of 7.5 cfs is recommended for the period April 15 to June 30.

Adult physical habitat is maximized at discharges of 12 - 14 cfs and appears to remain fairly high at greater flows. Juvenile cutthroat trout physical habitat is highest at flows of 7.5 - 9.5 cfs with relatively little habitat loss at higher flows. Fry physical habitat is high at low flows and again at relatively high flows. Under low flow conditions, channel velocities are low enough to provide fry physical habitat while at high flows flooded areas provide fry habitat.

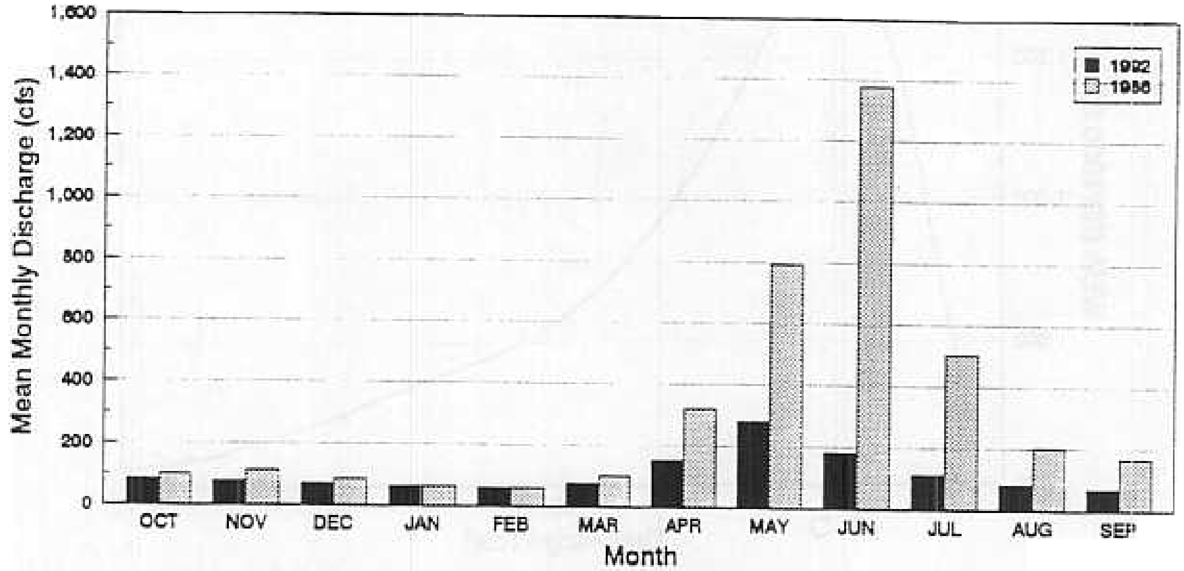

Figure 2. Mean monthly discharge at Smiths Fork River gage #10032000 for water years 1986 and 1992.

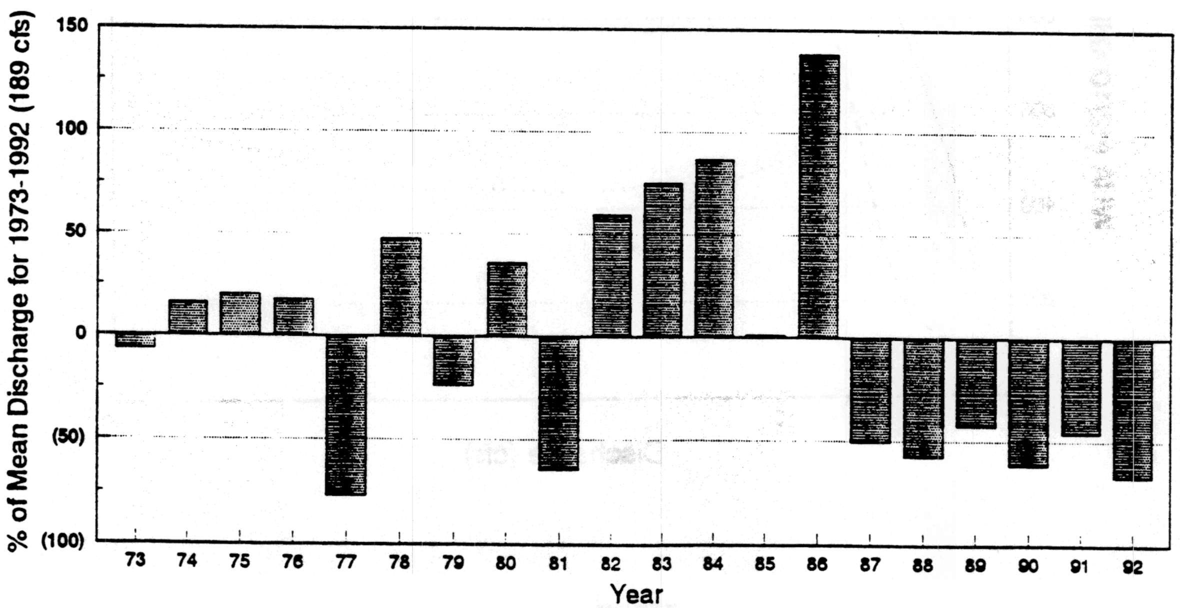

Figure 3. Percent deviation of annual discharge at Smiths Fork River gage #10032000 from the 20 year mean discharge (1972-1992; 189 cfs).

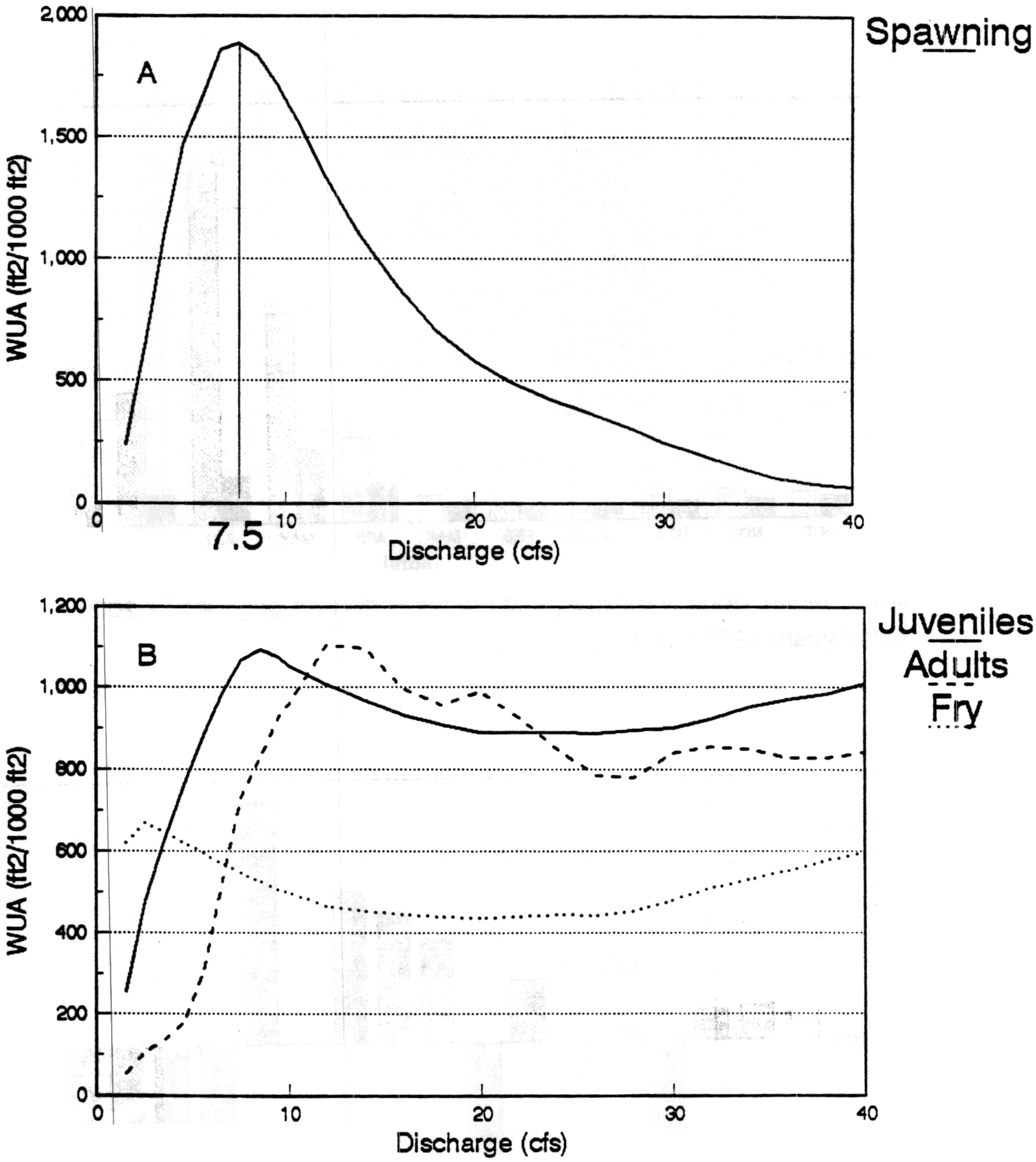

Figure 4. (A) Spawning Weighted Usable Area (WUA) for a range of discharges on Coal Creek. (B) Juvenile, adult, and fry WUA.

Habitat Unit Analysis

HQI analyses indicate that at existing average late summer trout flow conditions (estimated at 2.9 cfs based on September 1993 data), Coal Creek supports approximately 205 HUs. The analysis indicates that this number of HUs is maintained at a range of late summer flows of between 2.4 and 2.9 cfs.

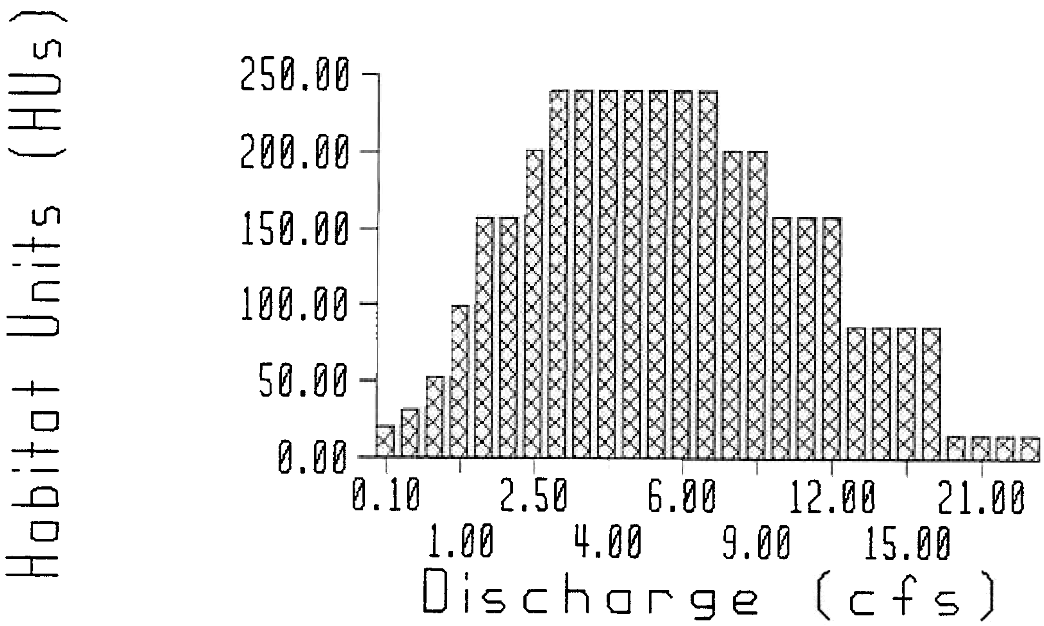

Figure 5. Trout habitat units at several late summer flow levels in Coal Creek.

A slight increase in late summer flow to just 3.0 cfs would result in 240.2 HU's and would maximize potential HU gains. In light of the 5-year Management Plans' emphasis on increasing Bonneville cutthroat trout populations in areas where they are low (Remmick et al. 1993), instream flow recommendations should attempt to maintain improved populations of Bonneville cutthroat trout. This strategy is appropriate considering the species Category II status and represents a legitimate effort to avoid listing of the species under the Threatened and Endangered Species Act. Listing of the Bonneville cutthroat trout may compromise state fisheries and land management opportunities in the Bear River drainage.

Based on the results of the HQI analysis and in consideration of the goals of the Bonneville cutthroat trout Management Plan (Remmick et al. 1993), an instream flow of 3.0 cfs is recommended to improve existing levels of trout production between July 1 and September 30.

Habitat Retention Analysis

Habitat retention results indicate that a flow of 1.8 cfs is required to maintain hydraulic criteria at all riffles to provide passage for all life stages of trout between habitats (Table 4).

Table 4. Simulated hydraulic criteria for three riffles on Coal Creek. Average daily flow = 4.9 cfs. Bank full discharge = 32 cfs.

	Mean Depth (ft)	Mean Velocity (ft/s)	Wetted Perimeter (ft)	Discharge (cfs)
Riffle 1	0.68	2.70	17.6	31.7
	0.58	2.17	13.3	16.4
	0.49	1.86	12.2	10.8
	0.38	1.53	11.3	6.5
	0.33	1.38	11.0	4.9
	0.24	1.15	10.5	2.9
	0.20[1]	1.05	10.2	2.1
	0.19	1.03	10.1	2.0
	0.18	1.00[1]	10.0	1.8[2]
	0.08	0.87	8.8[1]	0.6
Riffle 2	0.66	3.34	14.6	31.7
	0.49	2.56	13.2	16.4
	0.40	2.19	12.5	10.8
	0.32	1.83	11.2	6.5
	0.29	1.65	10.3	4.9
	0.24	1.36	9.0	2.9
	0.21	1.19	8.2	2.0
	0.20[1]	1.14	8.0	1.8
	0.17	1.00[1]	7.4	1.2[2]
	0.16	0.96	7.2[1]	1.1
Riffle 3	0.71	2.73	16.9	31.7
	0.47	2.39	14.9	16.4
	0.46	2.16	11.1	10.8
	0.35	1.87	10.0	6.5
	0.30	1.75	9.4	4.9
	0.26	1.62	8.5[1]	3.5
	0.24	1.56	7.9	2.9
	0.22	1.42	6.4	2.0
	0.20[1]	1.31	5.9	1.5[2]
	0.13	1.00[1]	4.7	0.6

1 - Minimum hydraulic criteria met
2 - Discharge at which 2 of 3 hydraulic criteria are met

Based on habitat retention results, an instream flow of 1.8 cfs is recommended for the October 1 to April 15 time period. According to PHABSIM results, adult Bonneville cutthroat trout have relatively low levels of physical habitat available at this flow (Fig. 4). However, flows would need to be increased to over 4.5 cfs before significant changes in physical habitat begin to accrue. It is likely that cutthroat trout populations are currently limited by lack of deep-water habitat. An instream flow of 1.8 cfs would likely maintain BRC populations at current levels.

Juvenile cutthroat trout will respond to 1.8 cfs in a manner similar to adults: more water may be better but a large, unreasonable increase would be needed to yield significant improvement (Fig. 4). Fry survival should be adequate at this flow.

Trout populations are naturally limited by low flow conditions during the winter months (October through March; Needham et al. 1945, Reimers 1957, Butler 1979, Kurtz 1980). Such factors as snow fall, cold intensity, and duration of cold periods can influence winter trout survival. Fish populations are influenced through the effects of frazile ice (plugged gills), anchor ice (ice dams and subsequent stranding), and collapsing snow banks (suffocation). Another important consideration is excessive metabolic stress incurred at low temperatures (Cunjak 1988).

These causes of winter mortality are all greatly influenced by winter flow levels. Higher flows inherently minimize temperature changes and subsequent trout mortality. Any reduction of natural winter stream flows would increase trout mortality and effectively reduce the number of fish that the stream could support. Therefore protection of natural winter stream flows up to the recommended flow is necessary to maintain existing survival rates of trout populations.

It is possible that the discharge of 1.8 cfs identified by the Habitat Retention Method may not be present at all times during the winter. Because the existing fishery is adapted to natural flow patterns, occasional periods of natural shortfall during the winter do not necessarily imply the need for storage. Instead, they illustrate the need to maintain all natural winter streamflows, up to 1.8 cfs, to maintain existing survival rates of trout populations.

FLOW RECOMMENDATIONS

Based on the analyses and results outlined above, the instream flow recommendations in Table 5 will maintain the existing Coal Creek Bonneville cutthroat trout fishery. These recommendations apply to a 0.8 mile segment of Coal Creek extending downstream from Sawmill Creek (R118W, T26N, S16, SE1/4) to the confluence with Smiths Fork River (R118W, T26N, S16, SW1/4).

This analysis does not consider flushing flow needs for maintenance of channel geomorphology and trout habitat characteristics. Because this stream is presently unregulated, flushing flow needs are adequately met by natural runoff patterns. If the stream is regulated in the future, additional studies and recommendations may be appropriate for establishing flushing flow needs for channel maintenance.

Table 5. Summary of instream flow recommendations to maintain or improve the existing Bonneville cutthroat trout fishery in Coal Creek.

Time Period	Instream Flow Recommendation (cfs)
April 15 to June 30	7.5
July 1 to September 30	3.0
October 1 to April 14	1.8[1]

1 - To maintain existing natural stream flows

LITERATURE CITED

Annear, T.C. and A.L. Conder 1984. Relative bias of several fisheries instream flow methods. North American Journal of Fisheries Management 4:531-539.

Binns, N.A. 1982. Habitat Quality Index procedures manual. Wyoming Game and Fish Department.

Binns, N.A. 1981. Bonneville cutthroat trout Salmo clarki utah in Wyoming Wyoming Game and Fish Department, Fisheries Technical Bulletin No. 5.

Binns, N.A. and F. Eiserman. 1979. Quantification of fluvial trout habitat in Wyoming. Transactions of the American Fisheries Society 108:215-228.

Bovee, K. 1978. Probability-of-use criteria for the family Salmonidae Instream Flow Information Paper No. 4. FWS/OBS-78/07.

Bovee, K. and R. Milhous. 1978. Hydraulic simulation in instream flow studies: theory and technique. Instream Flow Information Paper 5, FWS/OBS-78/33, Cooperative Instream Flow Service Group, U.S. Fish and Wildlife Service. Fort Collins, Colorado.

Butler, R. 1979. Anchor ice, its formation and effects on aquatic life. Science in Agriculture, Vol XXVI, Number 2, Winter 1979.

Conder, A.L. and T.C. Annear. 1987. Test of weighted usable area estimates derived from a PHABSIM model for instream flow studies on trout streams. North American Journal of Fisheries Management 7:339-350.

Cunjak, R.A. 1988. Physiological consequences of overwintering in streams; the cost of acclimatization? Canadian Journal of Fisheries and Aquatic Sciences 45:443-452.

Kurtz, J. 1980. Fishery management investigations - a study of the upper Green River fishery, Sublette County, Wyoming (1975-1979). Completion Report. Wyoming Game and Fish Department, Fish Division, Cheyenne.

Milhous, R.T., D.L. Wegner, and T. Waddle. 1984. User's guide to the physical habitat simulation system. Instream Flow Paper 11, FWS/OBS-81/43, U.S. Fish and Wildlife Service, Fort Collins, Colorado.

Milhous, R.T., M.A. Updike, and D.M. Schneider. 1989. Physical habitat simulation system reference manual - version II. Instream Flow Information Paper No. 26. U.S. Fish and Wildlife Service, Biol. Rep. 89(16).

Miller, D.D. 1977. Comprehensive survey of the Bear River drainage. Wyoming Game and Fish, Administrative Report.

Needham, P., J. Moffett, and D. Slater. 1945. Fluctuations in wild brown trout numbers in Convict Creek, California. Journal of Wildlife Management 9:9-25.

Nehring, R. 1979. Evaluation of instream flow methods and determination of water quantity needs for streams in the state of Colorado. Colorado Division of Wildlife, Fort Collins.

Nehring, B.R. and R.M. Anderson. 1993. Determination of population-limiting critical salmonid habitats in Colorado streams using the Physical Habitat Simulation System. Rivers 4:1-19.

Reimers, N. 1957. Some aspects of the relation between stream foods and trout survival. California Fish and Game 43:43-69.

Reiser, D.W., T.A. Wesche, and C. Estes. 1989. Status of instream flow legislation and practices in North America. Fisheries 14(2):22-29.

Remmick, R. 1981. A survey of native cutthroat populations and associated stream habitats in the Bridger-Teton National Forest. Wyoming Game and Fish Department, Administrative Report.

Remmick, R. and N.A. Binns. 1987. Effect of drainage wide habitat management on Bear River Cutthroat trout (*Salmo clarki utah*) populations in the Thomas Fork drainage, Wyoming. Wyoming Game and Fish Department, Administrative Report.

Remmick, R., K. Nelson, G. Walker, and J. Henderson. 1993. Bonneville cutthroat trout inter-agency five year management plan (1993-1997)

Appendix 1. Reach weighting used for PHABSIM analysis.

	STAID	LENGTH	WEIGHT	PERCENT	HABITAT TYPE
SEGMENT 1	0.00	8.65	1.00	19.89	RIFFLE
	17.30	16.65	1.00	38.28	RUN
	33.30	18.20	0.72	30.11	RIFFLE
	43.50			11.72	POOL
SEGMENT 2	0.00	3.50	1.00	5.74	RIFFLE
	7.00	7.25	1.00	11.89	POOL
	14.50	9.50	1.00	15.57	RUN/POOL
	26.00	8.05	1.00	13.20	RUN
	37.50	13.45	1.00	22.05	RUN
	46.00	19.25	0.61	19.06	RUN
	61.00			12.30	RIFFLE

Appendix 2. Suitability index data used for PHABSIM analysis. Adult, juvenile and fry data are from Bovee 1978 (substrate codes were changed to indicate no preference). Spawning index data is from Huff Ck., 1994.

	VELOCITY	WEIGHT	DEPTH	WEIGHT	SUBSTRATE	WEIGHT
FRY	0.00	0.00	0.00	0.00	0.00	1.00
	0.10	0.00	0.40	0.00	100.00	1.00
	0.15	0.09	0.50	0.12		
	0.25	0.38	1.00	0.64		
	0.30	0.70	1.05	0.71		
	0.35	0.90	1.10	0.77		
	0.40	0.99	1.15	0.88		
	0.45	1.00	1.20	0.96		
	0.50	0.99	1.25	0.99		
	0.55	0.90	1.30	1.00		
	0.60	0.82	1.55	1.00		
	0.70	0.69	1.60	0.98		
	0.75	0.63	1.65	0.92		
	0.80	0.58	1.70	0.85		
	0.90	0.50	1.80	0.74		
	1.00	0.43	1.90	0.66		
	1.25	0.30	2.00	0.59		
	1.50	0.20	2.10	0.54		
	1.60	0.17	2.20	0.50		
	1.70	0.14	2.30	0.46		
	1.85	0.10	2.45	0.41		
	2.00	0.08	2.55	0.39		
	2.20	0.05	2.70	0.37		
	2.30	0.04	2.85	0.36		
	2.50	0.03	3.05	0.34		
	2.75	0.02	3.20	0.32		
	2.90	0.00	3.30	0.31		
	100.00	0.00	3.50	0.26		
			3.70	0.20		
			3.80	0.16		
			3.90	0.10		
			3.95	0.06		
			4.00	0.00		
			100.00	0.00		
JUVENILE	0.00	0.00	0.00	0.00	0.00	1.00
	0.10	0.00	0.50	0.00	100.00	1.00
	0.20	0.12	0.65	0.08		
	0.30	0.30	0.70	0.10		
	0.40	0.59	0.80	0.18		
	0.45	0.83	0.90	0.26		
	0.50	0.95	0.95	0.32		
	0.55	0.98	1.10	0.50		
	0.65	1.00	1.20	0.68		
	1.05	1.00	1.30	0.94		
	1.15	0.99	1.35	0.98		
	1.25	0.97	1.45	1.00		
	1.40	0.94	1.50	1.00		
	1.50	0.91	1.60	0.98		
	1.60	0.87	1.65	0.93		
	1.65	0.85	1.70	0.87		
	1.70	0.82	1.75	0.82		
	1.75	0.77	1.80	0.78		
	1.85	0.56	1.95	0.70		
	1.90	0.46	2.10	0.62		
	1.95	0.42	2.25	0.56		
	2.05	0.32	2.70	0.41		
	2.10	0.28	3.00	0.28		
	2.15	0.25	3.30	0.17		
	2.30	0.19	3.55	0.10		
	2.40	0.16	3.65	0.07		
	2.65	0.12	3.75	0.05		
	2.75	0.10	3.90	0.03		
	2.85	0.07	4.15	0.00		
	3.00	0.00	100.00	0.00		
	100.00	0.00				

Appendix 2. cont.

	VELOCITY	WEIGHT	DEPTH	WEIGHT	SUBSTRATE	WEIGHT
ADULTS	0.00	0.00	0.00	0.00	0.00	1.00
	0.10	0.00	1.00	0.00	100.00	1.00
	0.25	0.31	1.05	0.02		
	0.35	0.49	1.10	0.06		
	0.45	0.61	1.15	0.14		
	0.55	0.70	1.20	0.68		
	0.70	0.81	1.25	0.88		
	0.80	0.87	1.30	0.94		
	0.90	0.92	1.35	0.96		
	1.00	0.96	1.40	0.98		
	1.10	0.98	1.55	1.00		
	1.20	1.00	1.75	1.00		
	1.70	1.00	1.85	0.97		
	1.80	0.98	1.95	0.92		
	1.85	0.97	2.00	0.88		
	1.90	0.95	2.05	0.82		
	2.00	0.90	2.10	0.78		
	2.15	0.80	2.20	0.71		
	2.25	0.71	2.30	0.65		
	2.35	0.59	2.45	0.58		
	2.40	0.51	2.60	0.53		
	2.50	0.30	2.75	0.49		
	2.55	0.17	2.95	0.44		
	2.60	0.11	3.25	0.38		
	2.65	0.08	3.60	0.32		
	2.70	0.06	4.75	0.17		
	2.80	0.03	5.00	0.13		
	2.85	0.02	5.15	0.10		
	3.00	0.00	5.25	0.08		
	100.00	0.00	5.35	0.05		
			5.50	0.00		
			100.00	0.00		
SPAWNING	0.00	0.00	0.00	0.00	0.00	0.00
	0.10	0.00	0.10	0.03	4.10	0.00
	0.20	0.01	0.15	0.08	4.20	1.00
	0.32	0.02	0.20	0.15	5.60	1.00
	0.45	0.03	0.25	0.30	5.70	0.00
	0.60	0.06	0.30	0.51	100.00	0.00
	0.76	0.11	0.35	0.70		
	0.91	0.19	0.40	0.90		
	1.01	0.25	0.45	1.00		
	1.10	0.32	0.50	1.00		
	1.22	0.44	0.55	0.82		
	1.32	0.54	0.60	0.64		
	1.41	0.64	0.65	0.41		
	1.50	0.74	0.70	0.23		
	1.60	0.83	0.75	0.12		
	1.72	0.93	0.80	0.05		
	1.81	0.98	1.00	0.01		
	1.91	1.00	1.50	0.00		
	1.97	1.00	100.00	0.00		
	2.09	0.96				
	2.19	0.91				
	2.31	0.80				
	2.41	0.71				
	2.50	0.60				
	2.62	0.47				
	2.72	0.38				
	3.20	0.00				
	100.00	0.00				